NOTES

Magnetostratigraphy and pavleo-environmental record of Tertiary deposits of Lanzhou Basin

YUE Leping[1], F. Heller[2], QIU Zhanxiang[3], ZHANG Li[1], XIE Guangpu[4], QIU Zhuding[3] & ZHANG Yunxiang[1]

1. Department of Geology, Northwest University, Xi'an 710069, China;
2. Institute of Geophysics, ETH-Honggerberg, CH-8093 Zurich, Switzerland;
3. Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China;
4. Provincial Museum of Gansu, Lanzhou 730050, China

Abstract **The Tertiary deposits of the Yongdeng section, the Lanzhou Basin were studied by means of magnetostratigraphy. The magnetostratigraphic sequences from Paleocene to Miocene were established, and the time scale for the corresponding stratigraphy and mammalian faunas was also established by referring to their correlation to the GPTS of BKSA95 (The geomagnetic polarity time scale which was thoroughly revised and updated by Berggreen et al. in 1995). In the end the paleo-environmental records and their relationship with the uplifting of the Tibetan Plateau were discussed. The results are as follows. The top boundary of the Xiliugou Formation is dated to be 51 Ma, i.e. Eocene. The Yehucheng Formation covers the time span of 51—31.5 Ma, i.e. from late Early Eocene to early Early Oligocene. The Xianshuihe Formation covers the time span of 31.5—15 Ma, i.e. from Early Oligocene to Middle Miocene. The lower member of the Xianshuihe Formation spans from 31.5 to 20.0 Ma, i.e. from Early Oligocene to early Early Miocene. The middle member is from 20.0 to 16.5 Ma, i.e. in the middle Early Miocene.**

Keywords: paleomagnetic stratigraphy, Lanzhou Basin, Tertiary, the Tibetan Plateau, paleo-environment.

The Lanzhou Basin, situated on the northeastern slope of the Tibetan Plateau, includes deposits of late Cretaceous, Tertiary and Quaternary, contains abundant mammalian fossils and records a great amount of information on the uplifting process of the plateau[1—3]. As a result, the Lanzhou Basin may be of great significance for better understanding the Tibetan Plateau, the Chinese northern continent, and climatic variation as well.

In the 1930s, Young and Bien found an assemblage of mammalian fossils in the Lanzhou Basin and erected a series of stratigraphic units, such as Changchuanzi, Xianshuihe, Guanyinsi and Wuquanshan formations. Since the 1980s, Qiu et al. have found abundant mammalian fossils in the basin and named them the Nanpoping, Xiagou, Zhangjiaping and Duitinggou local faunas[1,2]. The finding of these fossils is of great importance to studying the evolution of mammalian faunas, to reconstructing palaeozoo geography, especially to classifying the Oligocene/Miocene boundary. The present authors carried out the research work of magnetostratigraphy on Tertiary deposits of the Lanzhou Basin and erected the magnetostratigraphic sequence for Tertiary beds. This note provides the accurate time scale for the above study and offers the age data for reconstructing the uplifting process of the Tibetan Plateau.

1 Geological setting

The Tertiary stratigraphy (including Xiliugou, Yehucheng and Xianshuihe formations) overlying the Hekou Group of Cretaceous is mainly distributed in the north to the Yellow River. In the west it unconformably overlies the Hekou Group and extends to the Yehucheng Village. In the east it is covered by Quaternary deposits and only exposed from the Zhujiajing Village to the Gaoshancun Village. In the north it extends to the Xiajie Village and to the north further it is covered by loess. And in the south it extends to the southern side of the Yellow River (fig. 1).

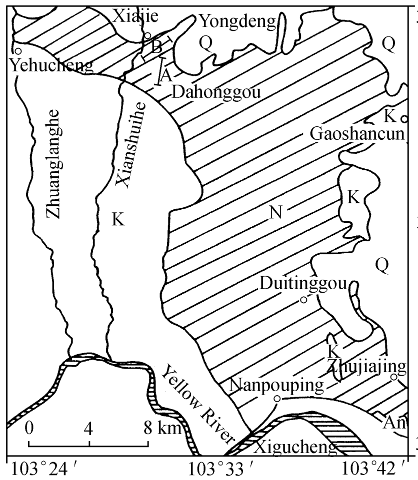

Fig. 1. Distribution of Tertiary deposits and sampling locality, modified from 1: 200000 Lanzhou Geology Map of 1965. An, Precambrian; K, Cretaceous; N, Tertiary; Q, Quaternary; A, Dahonggou Section; B, Xianshuihe Section.

In 1997, Qiu et al. described and classified the stratigraphy in detail when studying the Xianshuihe Formation[1]. In that study the authors adopted the stratigraphic classification when selecting sections, collecting samples and erecting the magnetostatigraphic correlation. The Dahonggou Section and the Xianshuihe Section are selected as the paleomagnetic sampling sites. The two sections are described as follows.

The Dahonggou Section, 1107 m in thickness:

4) The Middle Member of the Xianshuihe Formation: Red clay intercalated with white thick sandstone. It is the lower part of the Middle Member.

3) The Lower Member of the Xianshuihe Formation:

Red clay intercalated with yellow thick sandstone, including the Nanpoping and Xiagou local faunas.

2) The Yehucheng Formaiton: Dark-red clay and sandstone intercalated with layers of gypsum.

1) The Xiliugou Formation: Brick-red block sandstone.

The Xiajie Section, 289 m in thickness:

2) The Middle Member of the Xianshuihe Formation: Red clay intercalated with white thick sandstone. It is the upper part of the Middle Member, including the Duitinggou local faunas.

1) The Upper Member of the Xianshuihe Formation: Yellow sandy conglomerate intercalated with light brown clay, including the Quantougou local faunas.

Characterized by continuous strata, simple structure and stable occurrence, these two studied sections are located in the north-dipping monoclinal areas. Except rather friable massive sandstones of the Xiliugou Formation, the rocks of other formations are fine in grain size and suitable for magnetic study. The Dahonggou and Xianshuihe sections are 2 km apart and the white thick sandstones can be used as a marker band in the two sections.

2 Measurement and results

We collected 481 samples from the Dahonggou Section and 145 samples from the Xianshuihe Section. The strata of 66 m were overlapped in these two sections and 13 samples were repeated. The joined Yongdeng section is 1330 m thick.

All the samples were measured in the Paleomagnetic Laboratory of the ETH, Switzerland. Samples were thermally demagnetized using the TSD-1 thermal demagnetizer produced by the USA and measured in a superconductive magnetometer produced by 2G Company, the USA. The whole measurement was carried out in a field-free space. The demagnetization temperature gradient was as follows: 100, 200, 300, 400, 500, 550, 600, 620, 640, 650, 660, and 680℃.

Fig. 2(a) shows the demagnetization diagram of the normal sample. The first component removed by 100℃ is considered the secondary viscous remanence obtained in the present field. The second component is stable in the range of 100—600℃ and the vector trends to the origin. This component is the stable primary remanence acquired in the normal field. Fig. 2(b) shows the demagnetization diagram of the reversed sample. The first component is removed at 200—300℃ and is interpreted as the unstable viscous remanence. When the temperature reaches 300℃, the polarity direction is reversed. The direction of the second component which is stable at 400—600℃ trends to the origin. This component, displays the reversed primary remanence. The remanence of each sample was analyzed and the stable primary component of most samples was separated. Good effect of demagnetization suggests that the results of measurement are reliable.

The Tertiary deposits of the Yongdeng Section in clude Xiliugou (0—152 m), Yehucheng (152—592 m) andthe Lower and Middle members of the Xianshuihe Forma tion (592—1330 m) (fig. 3). The lower parts of the

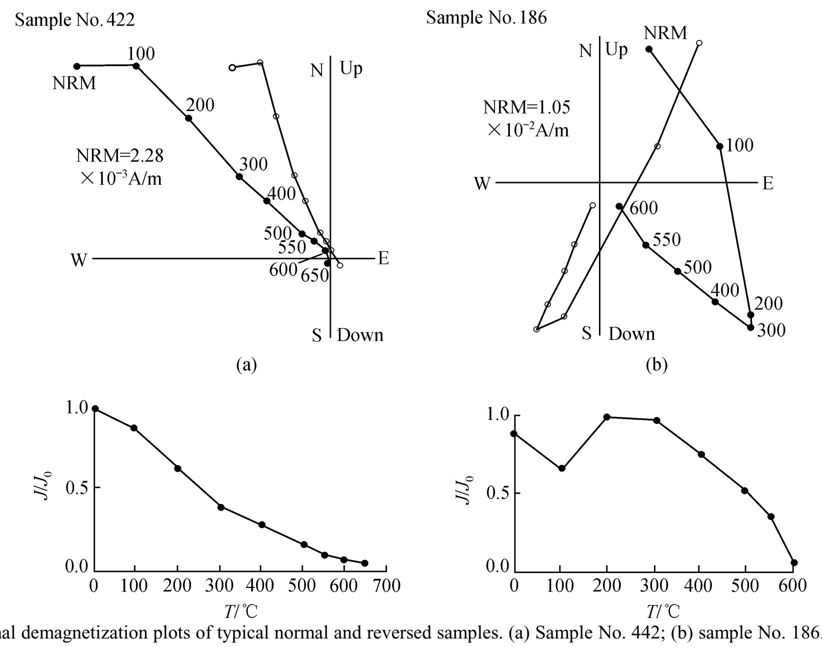

Fig. 2. Thermal demagnetization plots of typical normal and reversed samples. (a) Sample No. 442; (b) sample No. 186. The horizontal (vertical) component is marked with hollow (solid) circles. The top is the Zijdereld project and the bottom is the magnetic intensity plot.

Xiliugou Formation are poorly exposed so we only col lected samples on the upper parts (152 m). The results show that the Formation records 3 normal polarity zones. Compared with the geomagnetic polarity time scale (GPTS) revised by Berggreen et al. in 1995 (BKSA95)[4], they are corresponding to the C25n, C24n, and C23n. The top boundary of the Xiliugou Formation is dated to be ca. 51 Ma and the base of the section is about 58 Ma.

The Yehucheng Formation contains 9 normal polarity zones and 9 reversed zones. These 9 normal zones are congruent with the C13n, C15n, C163n, C17n, C18n, C19n, C20n, C21n and C22n (including the upper part of C23n), in which 3 long reversed zones consistent with the C12r, C13r and C20r are very stable and can be well correlated to the GPTS of BKSA95. By extropolation, the Yehucheng Formation covers the time span from 51 to 31.5 Ma.

The Xianshuihe Formation includes 19 polarity normal zones and 20 reversed zones. These 19 normal zones are corresponding to the C12n, C11n, C10n, C9n, C8n, C7n, C6Cn (C6Cn1n, C6Cn2n), C6Bn (C6Bn1n, C6Bn2n), C6An (C6An1n, C6An2n), C6n, C5En, C5Dn, C5Cn (C5Cn1n, C5Cn2n, C5Cn3n) and C5Bn. The Lower Member of the Xianshuihe Formation is corresponding to the upper C12r, C12n, C11n, C10n, C9n, C8n, C7n, C6nCn, C6nBn, C6nAn and lower C6r. The lower part of the Middle Member corresponds to C6n, C5En, C5Dn, C5Cn (C5Cn1n, C5Cn2n, C5Cn3n) and C5Bn. The base of the Xianshuihe Formation is about 31.5 Ma, and the top of the section is about 15 Ma.

3 Correlation between magnetostratigraphy and biostratigraphy

The Xiliugou Formation (0—152 m) covers the time span of 58—51 Ma, i.e. from Late Paleocene to early Early Eocene. Because no samples were collected from

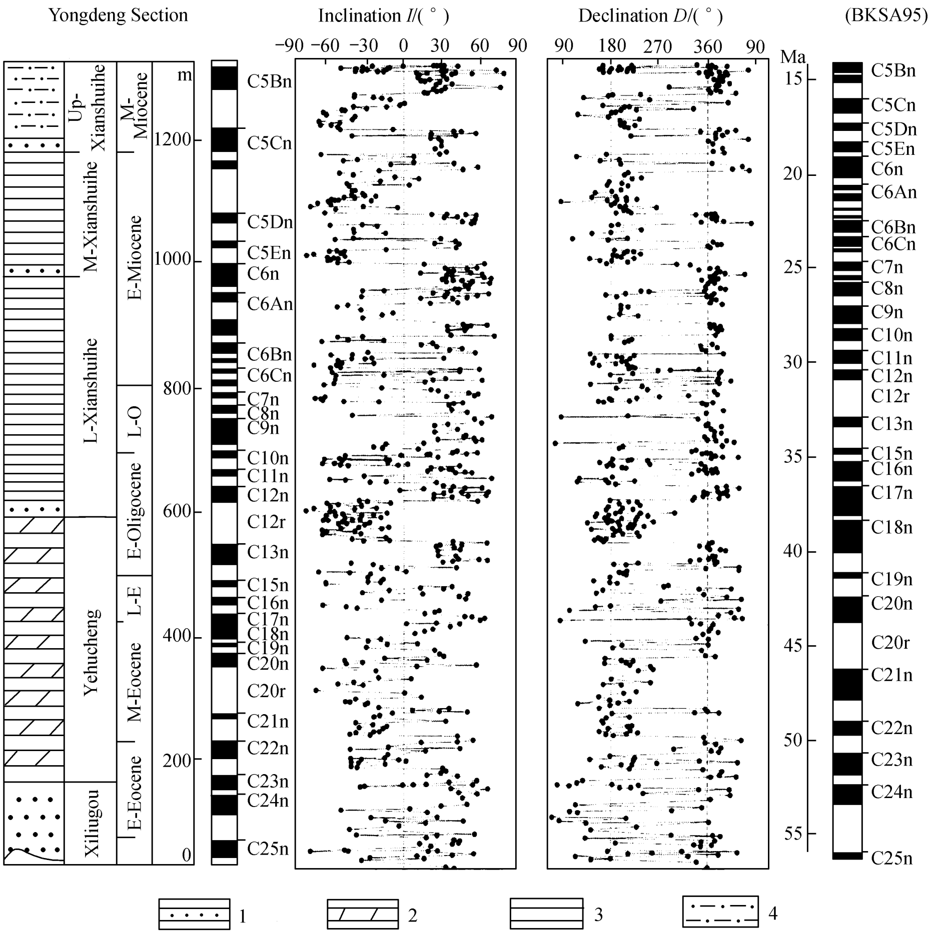

Fig. 3. Magnetostratigraphic classification of the Yongdeng Section and its correlation to the GBTS of BKSA95. 1, Sandstone; 2, clay intercalated with layers of gypsum; 3, clay; 4, interbedded sandy conglomerate and clay.

basal sanstone, it is estimated that the age of the Xiliugou Formation might be older. The Yehucheng Formation spans from 51 to 31.5 Ma, i.e. from late Early Eocene to early Early Oligocene. With white thick sandstone as the top boundary (973 m) and yellow thin sandstone as the basal boundary (592 m), the Lower Member of the Xianshuihe Fomation consists of deposits of fluvial and lacustrine phases and contains the Nanpoping and Xiagou local faunas. The age of formation is 31.5—20.0 Ma, i.e. from Oligocene to early Early Miocene. With the first sandstone layer in the bottom as the basal boundary (973 m) and the first layer of brownish yellow gravel sandstone as the top boundary (1177 m), the Middle Member is composed of red clay intercalated with white sandstone and includes the Zhangjiaping and Duitinggou local faunas. The Middle Member covers the time span from 20.0 Ma to 16.5 Ma, i.e. in the middle Early Miocene. The site of the Zhangjiaping local faunas may be dated as ca 20.0 Ma, 3.80 Ma earlier than the age of Oligocene/Miocene boundary (around 23.8 Ma). The Upper Member (1177—1330 m) is composed of interbedded brownish red sandstone, greyish yellow gravel layers with well rounded gravel and clay. The Upper Member covers the time span from 16.5 Ma to 15 Ma, i.e. in the early Middle Miocene.

4 Paleo-environmental records in the Lanzhou Basin and their relationship with the uplifting of the Tibetan Plateau

The Tethys Ocean between the Indian Plate and the Asian Plate was enclosed about 40 Ma ago. With underthrusting and collision of the Indian Plate, the Gangdisi Mountain in the south of the Tibetan Plateau uplifted, which resulted in the formation of the Gangdisi Mountain and related basins. It is the first phase of the Himalayan Movement[5]. The Lanzhou Basin is located on the northeastern slopes of the Tibetan Plateau, its deposits and recording information of the uplifting process of the Tibetan Plateau may reflect its uplifting periods and altitude of the plateau. The Yehucheng Formation (52—32 Ma) is composed of red sandstone and sandy clay intercalated with many layers of gypsum, which are typical sediments of playa under the dry climate, suggesting that this area experienced wide water sedimentation for about 20 Ma, reflecting a long-term, stable tectonic environment. Around 32 Ma ago, the basin basement began to uplift and the water body to shrink and dry. The Xianshuihe Formation represents the sediments of pluvian and braided river phases. A large number of unstable minerals and plant remains contained in the yellow sandstone reflect that the source area is near the low hill. In this period great changes took place in the climate, which is indicated by the end of sediments of playa and in tectonic environment reflected by the shrinkage, draining-out of the water body and uplifting of the surrounding mountains. This indicates that the first phase of wide uplifting of the Tibetan Plateau took place and also influenced the Lanzhou areas located in the northeastern slopes of the Tibetan Plateau. The time of the uplifting of Lanzhou areas was about 32 Ma ago, which might be later than that of Gangdisi areas.

After the first phase of uplifting, the tectonic movement was relatively calm and the surrounding mountains were subjected to denudation. And thick layers of red clay of flood plains were deposited in the basin. The Middle Member of the Xianshuihe Formation deposited at ca. 20 Ma is different from the Lower Member in sedimentation characteristics. The Middle Member is composed of many layers of white thick sandstone with pure sand grains and high maturity, reflecting that the source area is in the further highland and that the second phase of wide uplifting of the plateau occurred in the middle Early Miocene, at around 20 Ma (the C6n).

Shi considered that the second phase of the uplifting of the plateau would be in 25—17 Ma[5]. The research by Zhong indicates that this phase of uplifting occurred in 21—27 Ma[6]. According to the study on the Linxia Basin by Li, Fang et al., great environmental changes took place at 21.8 MaBP[7,8]. The Lanzhou Basin recorded a great environmental change at about 20 MaBP (the C6n), which reflects the second phase of uplifting influencing Lanzhou areas.

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